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NOTICES

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METEOROLOGICAL OFFICE

THE METEOROLOGICAL MAGAZINE

VOL. 89, No. 1,059, OCTOBER 1960

THE HORSHAM HAILSTORM OF 5 SEPTEMBER 1958

By F. H. LUDLAM, D.Sc. and W. C. MACKLIN, M.Sc.

Introduction.—On the evening of 5 September 1958 a severe hail and thunderstorm occurred near Horsham in Sussex. During the following week we toured an area in which it was reported that unusually large hailstones had fallen, interrogating people about the character of the storm as they experienced it. We were given consistent and graphic accounts. These we supplemented by an appeal for further reports from the voluntary observers in Surrey, Sussex and Hampshire, who had given invaluable help in our hail studies of 1956 and 1957. In addition Mr. W. Harper of the East Hill radar station provided radar records. With information from all these sources, which we gratefully acknowledge, we were able to learn something about the development and nature of the storm, and this we have summarized in the following paragraphs. A more detailed description of some aspects of the storm has been published elsewhere.¹

General aspects.—In the first days of September a moderately deep warm-sector depression approached the British Isles from the Atlantic, but became almost stationary 300–400 miles off south-west Ireland. The central pressure became about 984 millibars on the 2nd, but thereafter the depression occluded and slowly filled; the cold occlusion entered England from the south-west early on the 3rd, accompanied by a narrow rain belt with local thunderstorms. On the 4th the rain belt became quasi-stationary across central England, still with some thundery activity, and the front extended into eastern and southern France, but became weak and had disappeared from the official analyses during the morning of the 5th. Already on the 1st and 2nd the 1000–500-millibar relative topography showed a cold pool associated with the Atlantic depression, and this persisted as a prominent feature, so that early on the 5th the upper wind flow near the British Isles was dominated by a strong vortex centred south-west of Ireland, which existed throughout the troposphere and to above the 100-millibar level, with maximum wind speeds of 60–70 knots near the 300-millibar level. South-east England lay on the eastern fringe of this vortex, with high-level winds directed from slightly west of south, but in the lower troposphere a south-easterly air flow became established over central and northern France and south-east England, and there was an advection of warmer air northward across these areas during the 4th and 5th. There was a

slight fall of temperature in the high troposphere over south-east England, and this combined with the low-level warming increased the instability present throughout a deep layer. The warm advection was probably also associated with slight upward motion in a belt extending from western France across the Channel into eastern England, and in this belt considerable amounts of medium-level cloud and thickening high cloud were reported on the 5th. The C.R.D.F. network did not record any fœries in the area of this belt at 0430 GMT, but at 0600 GMT and afterwards small groups of fœries were recorded inland over Normandy and over the Channel north of the Normandy coast; they tended to shift northwards and at noon they were found only over the Channel, about mid-way between Cherbourg and the Isle of Wight.

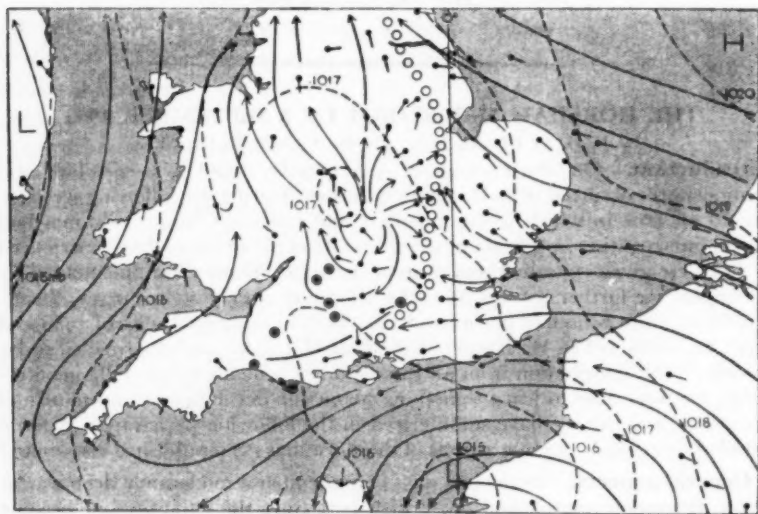


FIGURE 1—ISOBARS AND STREAMLINES, 1500 GMT, 5 SEPTEMBER 1958

The direction of the surface wind is shown at the observing stations marked by dots, and the chain of circles marks the position of a belt of convergence in the wind flow.

At this hour the surface chart shows a south-easterly pressure-gradient over northern France, England and Wales; although inland over England the gradient is very weak, the streamlines of the wind near the ground show a consistent flow pattern of south to south-east winds, light in western and central areas and moderate in the east. The 1500 GMT chart shows a shallow depression near the north coast of France and a shallow high-pressure area over the Midlands, where there is a pronounced diffluence of the streamlines of the surface winds, and a distinct belt of confluent winds has developed along a line extending from north-east England to west of London and to near Portsmouth. Figure 1 shows that in this belt there is a strong convergence, probably leading to low-level upward motion and enhancement of the cumulus developing inland. According to Figure 2 in and just to the east of the belt the wet-bulb potential temperature of the air at screen-level reaches a maximum of about 22°C, and consequently in and just east of the belt the temperature-excess of

air rising adiabatically from near the ground also attains maximum values of about 5°C at 700 millibars and as much as 9°C at 500 millibars. Not only, therefore, does the convergence of the surface winds into the belt stimulate the convection: here also is the greatest instability to support it. In practice the air rising in growing cumulus cools more rapidly than at the saturated adiabatic rate and if the environment over the Midlands and East Anglia possessed the

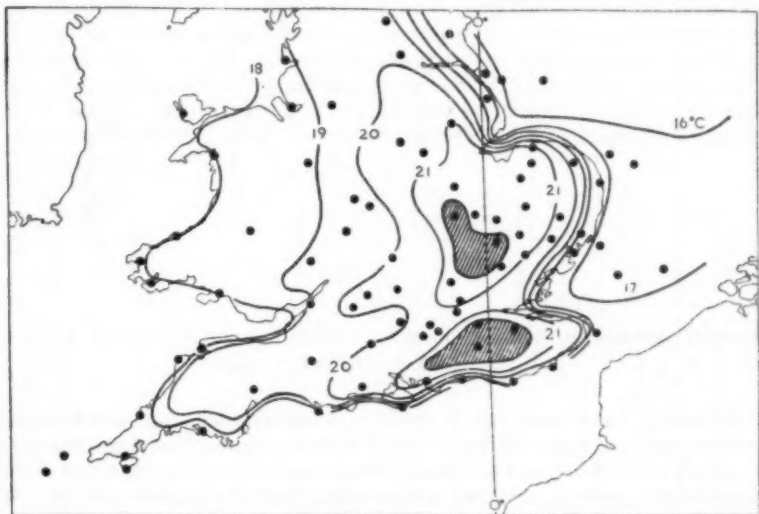


FIGURE 2—DISTRIBUTION OF WET-BULB POTENTIAL TEMPERATURE AT SCREEN-LEVEL, 1500 GMT, 5 SEPTEMBER 1958

The dots mark the positions of observing stations. Within the shaded regions the wet-bulb potential temperature exceeds 22.0°C .

rather stable layer indicated on the Hemsby sounding between about 730 and 600 millibars, then it is probable that the cumulus tops would not attain these levels. This stable layer is not present on the sounding made at Crawley (Figure 3), but it is probably significant that the high temperature there at 850 millibars would permit convection from the ground to exceed this level only in the area where the screen wet-bulb potential temperature exceeded 22°C . Even higher 850-millibar temperatures, apparently due to subsidence in the fringes of the anticyclonic circulation over eastern France and Germany (from which regions the air was drawn), occurred over northern France, and seem to have prevented any considerable development of thunderstorms there: from the afternoon charts it appears that over most of north-eastern France cumulus did not form at all.

Early stages of the storm.—Between 1400 and 1500 GMT several rather small radar echoes were located in a belt extending northwards from 10–20 miles south of the Isle of Wight to near Southampton. Some of these echoes were short-lived, and they mostly moved from 180 – 190 degrees at speeds of 25–30 knots, corresponding to the winds reported at noon from Crawley at medium-cloud levels, and to a nephoscope measurement of 195 degrees 20 radians per hour on altocumulus castellanus made by Mr. Moon at 1600 GMT

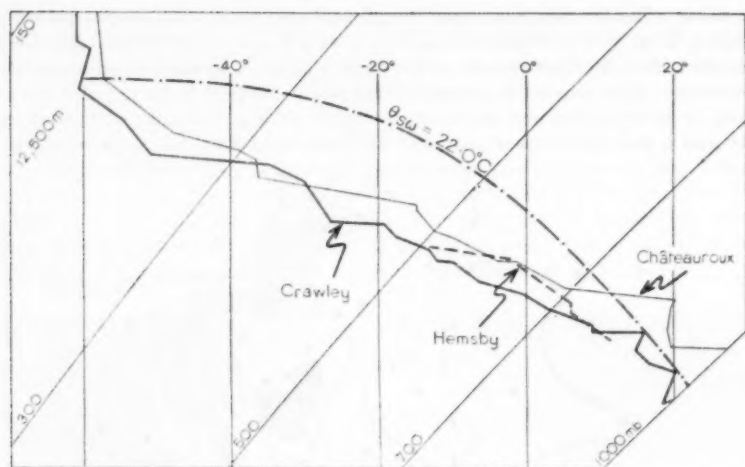


FIGURE 3—SOUNDINGS MADE AT CRAWLEY, HEMSBY AND CHÂTEAUROUX, FRANCE, AT 1200 GMT, 5 SEPTEMBER 1958

at Pevensey. An aircraft which made a reconnaissance over mid-Channel between 1000 and 1100 GMT found 4/8 of shallow cumulus base 8,500 feet near the mouth of the Seine and an isolated heavy shower 20 miles south-east of the Isle of Wight, while at 1425 GMT another aircraft off the English coast at 3°W reported large raindrops from cumulus with base at 7,000 feet, with tops estimated at 15,000 feet. The radar echoes and showers near the Isle of Wight were therefore caused by clouds with high bases; some of these may have formed inland over France, but evidently the clouds continued to develop as they moved northward over the Channel even though there was no convection from the sea surface, which was here and there covered by patches of mist or fog and very low stratus. Inland over England there was still some mist and low stratus at noon, but temperatures were rising and by 1500 GMT most stations were reporting well broken cumulus. In southern, central and eastern England there were patches of altocumulus with some castellanus, and a belt of thickening cirrus extended from north-west France into eastern England and the southern North Sea.

A correspondent (Mr. Leal) at Newport in the Isle of Wight has given a detailed description and a drawing of the appearance of the sky in the early afternoon, from which it is clear that the first rain there fell from clouds growing in the medium levels. At this place the first brief shower of very large drops fell at about 1230 GMT. Between 1300 and 1400 GMT heavier showers with thunder occurred in the west of the Isle of Wight, and some irregularly-shaped hail in pieces up to one inch across fell near Totland. Near Brook, on the south-west coast, another correspondent (Miss Thornton) observed a four-minute fall, beginning at 1350 GMT, of flat plates of "mushy" ice from one to three inches across, containing harder nuclei, but which melted on the ground as they were succeeded by torrential rain and thunder. It appears, however, that up to this time hail had fallen only in isolated small localities.

Towards 1600 GMT the storms became organized into a belt some 50 miles long extending from east of the Isle of Wight to north of Andover (Figure 4). Intense rain, without any hail but with almost continuous lightning, fell in the eastern part of the Isle of Wight and an expanding echo developed at the southern end of the belt of showers. At about 1600 GMT this storm reached the south coast just west of Selsey Bill, and accounts of it have been received from two places marked "a" on Figure 4. According to these descriptions there was a very heavy shower lasting about 20 minutes; at the western position there was hail of pea size for only three minutes but at the eastern position, nearer the rear of the storm, there were large scattered raindrops for a few minutes at the onset, followed by increasingly intense hail which became very severe for about 10 minutes; the diameter of the largest stones was $\frac{1}{2}$ inch. Rain fell at the end of the shower.

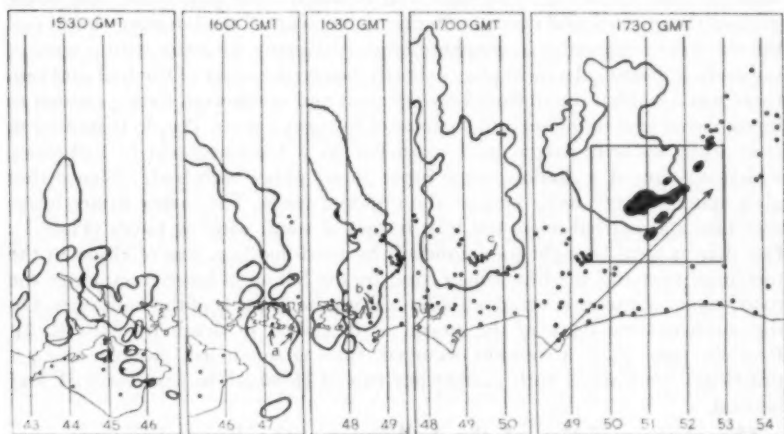


FIGURE 4—POSITIONS OF RADAR ECHOES OBSERVED FROM EAST HILL, 1530-1730 GMT, 5 SEPTEMBER 1958

The dots show the positions of voluntary hail observers. Apparently no hail fell in the heavy rains in the early stages of the storm (section 1, 1530 GMT). The intense part of the storm was its rear (southern) end, and observers at positions "a" (on section 2, 1600 GMT) reported hailstones of up to $\frac{1}{2}$ inch diameter, at positions "b" (section 3, 1630 GMT) of 1 inch diameter, and at position "c" (section 4, 1700 GMT) of 2 inches diameter. The black areas in the last section show where stones fell of diameter 7 centimetres or more (about 3 inches). These are based on accounts collected from over 300 people in the area shown by the rectangle. The arrow shows the direction of displacement of the rear of the storm. The vertical lines are National Grid reference lines ten kilometres apart.

The storm in the Horsham area.—The storm now moved inland, successive positions of the rear edge of the echo lying on a line orientated from about 225 degrees (Figure 4), although where detectable the motion of individual parts of the echo masses continued to have a velocity of 25-30 knots from 180-190 degrees. An isolated storm which formed towards 1500 GMT near Bedford showed detail with about the same motion, but its radar echo decayed and had practically disappeared at 1600 GMT. The main belt of storms moved steadily towards the north-east and caused intense showers and some hail in a number of places, but the strongest development continued to be associated

with the southern end of the belt. By 1630 GMT hailstones of 1 inch (2.5 centimetres) diameter were reported (from the positions marked "b" on Figure 4), and by 1700 GMT stones of diameters up to 2 inches (5 centimetres) (at the place marked "c" on Figure 4). The intensity of the hail-falls continued to increase, and reached a maximum about 1730 GMT, at which time the position of the main echo is as shown on the last section of Figure 4. The black areas on this diagram are those in which the largest hailstones had diameters of 7 centimetres or more; these mostly occur within an area indicated by a rectangle from which by correspondence and interrogations made during tours on several following days we collected over 300 reports of the characteristics of the hailstorm. The largest stones fell near the town of Horsham, and especially in an area several kilometres across lying just west of Horsham.

In the heart of the storm the weather was frightening. It became very dark with the approach of the cloud mass, and although it was practically calm at the ground the unusual and even conflicting movements of the lowering clouds and the extremely oppressive atmosphere impressed many witnesses with a sense of impending disaster. In most places shortly before the onset of the hail and rain there was a sudden squall from between west and north-west, strong enough to break down tree branches and sometimes to uproot trees. People hastening to close windows were driven back to shelter by a bombardment of hailstones, which arriving at a shallow angle broke many panes with such violence that glass splinters were flung against the opposite walls. The larger stones broke roof tiles and carried away the lead frames of small window panes (Plate I). Car drivers were brought to a standstill by road-flooding, loss of vision in the torrential rain and swirling foliage, and by the felling of large trees across the road; some cars were covered with dents from the impacts of the hailstones. On the south-western flank of the storm, as described in detail by Miss E. H. Rowsell (page 252), a tornado occurred, causing much tree damage along a practically continuous path passing just east of Horsham to near Gatwick and beyond.

The characteristics of the hailstones.—The largest hailstones were reported to be like tennis or cricket balls, or half grapefruits. Not all were spherical; many were dimpled on one side, like a doughnut but without a hole, while some were flattened discs, rather like half-crowns, and others again were irregular and even "jagged" lumps of ice. One correspondent picked up from his lawn a stone which was "5 to 6 inches long and like a piece of glass . . . I did not like the look of it and dropped it back on the ground." Many people measured the diameters and the circumferences of the large stones, or weighed them; several weights of 4 ounces were recorded while even heavier stones were measured by Mr. Forrest (three of $4\frac{1}{2}$ ounces), Mr. King (between 4 and 5 ounces), Mr. Browning of north-west Horsham (6 ounces) and Mr. Shortt of Southwater ($6\frac{1}{2}$ ounces "to within about 2 grams"). Several people tried to preserve stones in household refrigerators, but because of a power-cut in the area only those stones placed in deep-freeze boxes remained about the same size after a few days. We were able to examine stones kept by Colonel Cumming near Slinfold (here we measured the density of a large stone to be practically that of pure ice), smaller stones preserved at a house south-east of Horsham, and larger stones which still possessed diameters up to 6 centimetres (weight $2\frac{1}{4}$ ounces) at Okehurst Farm (Plate II) and at Malham Farm, which are both about 10 kilometres west of Horsham. Of five large stones which we opened,

four had small internal cores of transparent ice, and the other an opaque core; one smaller stone of marble size also had a clear core. All the large stones were hard and evidently had a density close to that of pure ice: they bounced high from paths and road surfaces, and buried themselves in lawns so that their tops were about level with the undisturbed surface; pits were left in the lawns when the stones had melted, and we measured several which were 5 centimetres deep and 7 centimetres across, and in Horsham one which was 5 centimetres deep, 13 long and 11 across.

Observations of the height of the cloud tops.—Between 1500 and 1600 GMT a pilot from Dunsfold flying over the Isle of Wight had found "firm" cloud tops at 40,000–43,000 feet with "cobweb" cirrus above; towards 1730 GMT pilots flying at Farnborough reported cloud tops to 38,000–40,000 feet and at 1730 GMT a report from the Air Traffic Control at London Airport indicated that there were several echo tops to 40,000 feet in an area to the west and just north of London. The Control Supervisor recalled that at some time during the afternoon a controller had called out that he could see tops to 56,000 feet, and at 1815 GMT radar echo tops south-east of Epsom were reported to be at 45,000 feet. About this time Dunsfold Traffic Control recorded that one of their pilots was still in cloud at 43,000–45,000 feet and an unconfirmed report said that another had failed to break cloud at 48,000 feet. At 2000 GMT the radar at London Airport showed a large echo mass bounded by a line Oakington–Woodbridge–Crowborough–Horsham–Oakington, drifting slowly north, with echo tops to 45,000–48,000 feet. Although the radar reports of tops to 48,000 and even 56,000 feet may be errors due to side-lobe effects produced by intense precipitation at lower levels, the additional evidence of the aircraft reports strongly suggests that the level of the highest tops rose during the afternoon and was probably at least 48,000 feet at the time of the severe storm in the Horsham area.

Late stages of the storm.—A further group of storms formed between Petersfield and Farnham about 1745 GMT, and another north of Brighton somewhat later, and these probably amalgamated with the Horsham storm and its northern extensions to form the large complex group which the radar reported at 2000 GMT to be straddled across the London area from Suffolk to north Sussex. The most active part of the storm continued to move north-eastwards, and according to the last of the day's C.R.D.F. observations was centred a little north-east of Ipswich at 2100 GMT; it was not located over the North Sea at 0430 GMT the following morning, and so presumably had died out some time after crossing the coast of East Anglia.

It is interesting that although the storm produced very heavy rainfall and unusually impressive displays of lightning during the evening, it nowhere gave hail-falls of the severity of those in the Horsham area. This is clearly shown by the reports of the rainfall observers of the Meteorological Office, according to which the largest stones which fell east and north-east of London were about the size of marbles.

Acknowledgment.—One of the authors (W. C. Macklin) is indebted to the Commonwealth Scientific and Industrial Research Organisation of Australia for their support of studies in which this work has been included.

REFERENCE

- I. LUDLAM, F. H. and MACKLIN, W. C.; Some aspects of a severe storm in S.E. England. *Nubila, Verona*, 2, No. 1, 1959, p. 38.

STORMS OF 5 SEPTEMBER 1958, OVER SOUTH-EAST ENGLAND

By E. H. ROWSELL, B.Sc.

Introduction.—The remarkable storms that affected south-east England on the evening of 5 September 1958 were amongst the most severe ever known in that area and extensive damage was caused by hailstones, tornado winds and extremely heavy rainfall. The overall distribution of rainfall and hail, the track and effects of the tornado and accounts of storm damage are discussed in the present article; a more detailed account of the distribution of hailstone sizes in the Horsham area, together with an account of the synoptic situation and descriptions of the sferic activity, are given in other articles in this issue (pages 245 and 257).

We acknowledge with thanks replies to our letters from some 750 rainfall observers. The information they sent has been tabulated and mapped, thus forming the basis of this article. A map showing tornado tracks together with photographs and notes of severe damage were supplied by Mr. G. F. W. Clapp of the London Forecasting Office.

Distribution of rainfall in time.—Two major storm-tracks were apparent and it should be noted that the times given are of the onset of rain and will differ from times quoted elsewhere for maximum intensity of electrical activity.

1. The first storm approached the Isle of Wight about 1300 GMT and moved north-eastwards. Heavy rain began at Portsmouth about 1530, Petersfield about 1600, Guildford about 1700, south London about 1800, Chelmsford after 1900, Colchester at 2030 and over the Stour estuary at 2100 GMT.

2. The second storm brought heavy rain to the hinterland of Brighton at about 1800 GMT and moved in a more northerly direction, reaching Rochester about 1900 and east Essex about 2000 GMT.

Over north-west Kent and nearby parts of Surrey and Sussex and also over Essex the two storms seemed to merge and large areas had more than three inches of rain, much of which fell within a period of two hours.

Distribution of rainfall in space.—The map of rainfall for the 24 hours 0900 GMT on 5 September to 0900 GMT on 6 September (Figure 1) approximates closely to that for the falls during the storms. More than an inch of rain fell in a wide belt from near Chichester to Earls Colne and Colchester, a distance of nearly 100 miles. This was joined about Westerham and Sevenoaks by another belt which began to the north of Haywards Heath. The whole area was about 25 miles wide south of London (extending from Sutton to Tonbridge) and over 34 miles wide to the north-east (from near Harlow to Foulness Island): taking into account a probable extension eastwards over the North Sea the width here may well have exceeded 40 miles. There was more than 4 inches in Kent at Eynsford and at Knockholt Waterworks a fall of 5·14 inches for one day is the heaviest yet recorded in Kent or in any county nearer to Kent than Wiltshire or Norfolk. Measurements, by planimeter, of the rainfall distribution, drawn on a quarter-inch map, give the following areas in square miles for falls of 1·0 inch or more (Table 1).

TABLE 1—RAINFALL DISTRIBUTION

Rainfall exceeding	1·0	1·5	2·0	2·5	3·0	3·5	4·0	5·0 inches
Area ...	2550*	1219	724	352	150	58	10	0·5 sq. miles

* Including estimate of about 450 sq. miles over the sea.

Intense falls of rain.—Many of the heaviest falls in west Kent have no exact timing and so cannot be included in the strict category of intense falls within a period of two hours (see Table II). The most interesting, 5·14 inches at Knockholt Waterworks, is believed to have fallen in about two hours and should certainly rank as "very rare". The amount of 3·55 inches, measured at Chevening Gardens about 1½ miles to the south-east, is stated to have fallen in 2½ hours whilst two other Sevenoaks' observers (one at Cramptons Road the other at Oak Lane) recorded 3·78 and 3·36 inches respectively in two hours from 1830 GMT.



FIGURE 1—RAINFALL FOR THE 24 HOURS 0900 GMT, 5 SEPTEMBER TO 0900 GMT
6 SEPTEMBER 1958

Scale shown by National Grid figures.

Seventy-eight intense falls of less than two hours' duration were accepted as worthy of note according to the classification used for *British Rainfall*,¹ namely, noteworthy, remarkable, very rare. The distribution of these on a county basis is given in Table II.

TABLE II—DISTRIBUTION OF INTENSE FALLS WITHIN TWO HOURS

County	Noteworthy	Remarkable <i>number of falls</i>	Very rare
Kent	3	6	12+others unclassified
Essex	9	7	4
Sussex	4	6	3
Surrey	9	6	1
London	3	3	—
Hampshire	1	—	—
Huntingdonshire	1	—	—

Falls at Knockholt and Sevenoaks have already been discussed and others coming into the "very rare" category (frequency at one station equal to or less than one in 160 years) are listed in Table III.

TABLE III—"VERY RARE" FALLS

County	Rainfall station	Amount <i>inches</i>	Duration <i>minutes</i>
Essex	Tilbury (Gray's Sewage Works)	3' 17	120
Essex	Chelmsford (Galleywood)	2' 98	120
Kent	Seal (Kemsing Pumping Stn.)	2' 43	115
Kent	Edenbridge Pumping Stn.	3' 16	110
Kent	Meopham Pumping Stn.	3' 43	105
Kent	Wilmington (Orchard Way)	2' 74	105
Kent	Dartford (Central Park)	2' 76	100
Kent	Dartford (Christchurch Rd.)	2' 94	95
Kent	Horton Kirby (Court Lodge)	> 3' 50	90*
Essex	Wickford (Dollyman's Farm)	3' 27	90
Essex	Chelmsford (Sandford Mill)	2' 73	60
Sussex	Weir Wood Reservoir	2' 50	60,
Sussex	Horsted Keynes (Cinder Hill)	2' 33	60
Surrey	Caterham (White Knobs Way)	2' 15	50
Kent	Bromley (Keston)	2' 30	45
Kent	Bexley Heath (Danson Park)	2' 44	40
Sussex	Kirdford (Hills Green)	2' 00	30
Kent	Sidcup	2' 50	20

* Gauge overflowed.

Distribution of hail.—The map (Figure 2) shows the incidence of hail as reported by rainfall observers. A spot denotes that no hail was observed; a triangle that hail fell but that the size was not specified; and the figures are those adopted by Mr. Ludlam for his detailed survey of the Horsham district² in which hailstones are graded from 1 (diameters up to 0.5 centimetres) to 7 (diameters of 9.0 centimetres or more). The overall picture is supplemented by isopleths sent by Mr. Ludlam which show areas near Horsham where hailstones graded as 6 or 7 were observed by local inhabitants. The map also shows the path of the tornadoes.

Tornadoes.—Mr. G. F. W. Clapp of the London Forecasting Office visited the district within a week of the storm and plotted a track showing the path of the main tornado from Coolham six miles south-west of Horsham, to Ifield seven miles north-east with a probable path extending nearly to Oxted. He also plotted the track of a minor tornado which possibly began near Petworth, passed across Horsham and Three Bridges to Crockham Hill near Edenbridge. Both tornadoes appear to have passed near Horsham at about 1730 GMT. Mr. Clapp gave the following account of the two tracks which was supplemented by a number of small photographs:

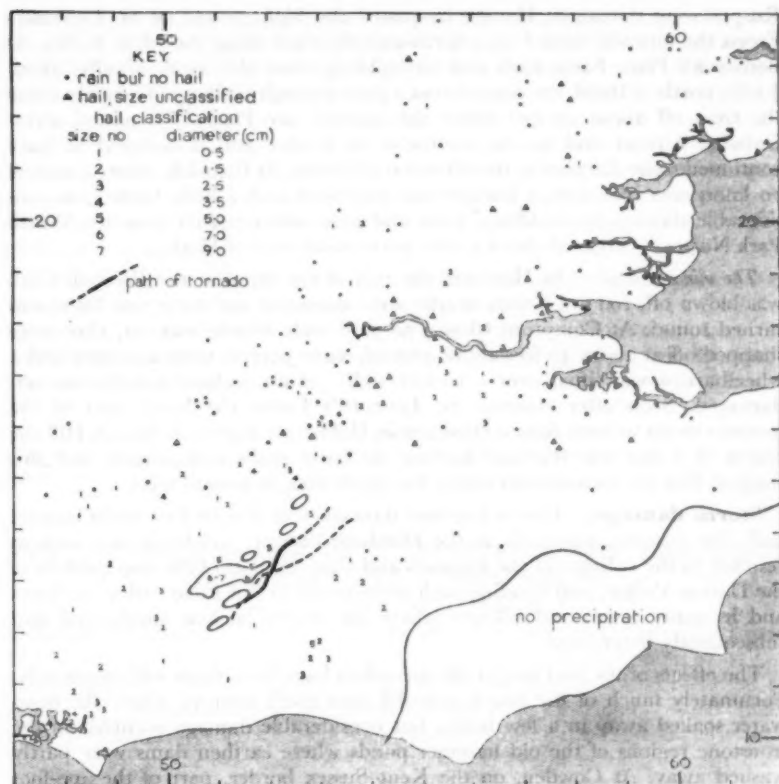


FIGURE 2—HAIL SIZE ON 5 SEPTEMBER 1958

The isopleths enclose areas with maximum hail diameter ≥ 7 cm, based on a more detailed map by Ludlam and Macklin.²

Scale shown by National Grid figures.

The main tornado.—Tornado cloud was observed in the Coolham area, and near Southwater one tree was twisted off about 4 feet from the ground. At Southwater Street a garage was wrecked, petrol pumps being torn from the ground. Orchards across the road were badly damaged. From here to Coolhurst there was intermittent damage to trees. At Coolhurst (an estate south-east of Horsham) the tornado entered the grounds at a height of about 30 feet but lowered immediately to ground level, twisting off 300-year-old walnut trees and cutting a path about 20 yards wide. It then took a north-north-easterly track and damage was less marked until it crossed the Horsham–Crawley road. Here trees a foot in diameter were twisted off (one being uprooted and carried so that its roots were ten feet from the hole in the ground whence they came), sheets of corrugated iron were picked up and wrapped round trunks and branches (see Plate V) and a barn was demolished. Damage to trees was extensive along the track to Ifield (see Plate III) and in addition a brickworks was destroyed, and a farm and the Lamb Inn about a mile to the south-east of

Rusper were damaged. Having by-passed the high ground of St. Leonard's Forest the tornado turned on a north-easterly track along the Mole Valley. At Bonwyck's Place Farm roofs and outbuildings were damaged. Finally, about $\frac{1}{2}$ mile north of Ifield, the tornado cut a path through a clump of pines twisting the trees off about 20 feet above the ground (see Plate IV), passed across Gatwick Airport and to the south-east of Horley and is believed to have continued some distance in the direction of Oxted. At Gatwick, where a gust of 70 knots was recorded, a hangar was destroyed and a little further on considerable damage to buildings, trees and glass was reported from the Worth Park Nursery—situated about a mile to the south-east of Horley.

The minor tornado.—In Horsham the roof of the stand at the Football Club was blown off, roofs of houses nearby were damaged and a car was lifted and turned round. At Comptons Clew a 50-yard wide swathe was cut, elms were snapped off at about 40 feet above ground, some poplars were uprooted and a wheelbarrow was lifted over a 10-foot wall; yet an orchard nearby was undamaged. Soon after entering St. Leonard's Forest the lower part of the tornado seems to have degenerated but in Holmbush Forest on Beacon Hill the centre of a tree was removed leaving the outer limbs undamaged, and this suggests that the tornado was only a few yards wide at ground level.

Storm damage.—The widespread damage was due to four main causes: hail; the tornado, especially in the Horsham district; weight of rain such as resulted in the collapse of the supports and vines in most of the hop gardens of the Darent Valley; and flooding such as occurred in the Eden valley, in Essex and in many towns and villages where the sewers became surcharged and subsequently overflowed.

The effects of the hail and of the tornadoes have been dealt with separately. Fortunately much of the heavy rain fell over chalk country where the flood water soaked away in a few hours, but considerable damage occurred in the ironstone regions of the old hammer ponds where earthen dams were partly washed away. At Cowden, on the Kent-Sussex border, part of the 400-foot Furnace Mill dam was eroded, a road was damaged and buildings undermined. The observer at Penshurst Place reported the drowning of cattle and sheep. From Horsted Keynes the Secretary to the Ashdown and General Land Company at Cinder Hill reported a fall of 2.33 inches in an hour. He states, "this quantity of rain in so short a time caused great damage to ponds, dams, overflows and to roads running through the estate. The flooding was increased by the streams which come down from Ashdown Forest to the north. We were suddenly hit by a wall of water some 220 feet wide and 4 to 5 feet high in the middle." At Nobels Farm, near Horsted Keynes, 300 pullets were drowned and the Holy Well Pumping Station of the Mid-Sussex Joint Water Board was partly inundated with a consequent, temporary, curtailment of the water supply.

It is not possible to include the wealth of information sent in by observers, in this account but the following description is given of the storm and of storm damage. It was sent by Mr. Lionel Baker of Hills Green, Kirdford near Billingshurst, a parish noted for its Cox's Orange apple orchards:

"We lost about 10,000 bushels of apples from 50 acres of orchards, the remainder, left on the trees, were nearly all hail-marked and worthless. The day had been fine and sunny but about 1645 GMT a black mass of cloud approached

from the west and by 1700 a storm of wind, hail, thunder and lightning was raging which lasted for half an hour. It was difficult to see what was happening as the air was full of flying leaves, twigs, branches, hail and rain. This house, although on a hill, was soon invaded by water as every drain was blocked by debris and hail. I was able to get out about 1800 and measured several hail-stones averaging about $\frac{3}{4}$ inch across. The garden was a scene of desolation, flattened with vegetables destroyed. Next day revealed half the apple crop on the ground and the rest cut and scarred. In exposed parts leaves were stripped from the trees and the bark was cut and split. This last damage may affect the crops for a year or two.

"The strip of country affected in this parish, as far as I can ascertain, was one mile wide but Kirdford village escaped the hail. Electricity was cut off in Kirdford until the 6th and telephones for two or three days in some places. A well-informed estimate of the damage in this area is £300,000 but the after-effects cannot be estimated."

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THE THUNDERSTORMS OF 5 SEPTEMBER 1958—LIGHTNING DISCHARGES AND ATMOSPHERICS

By F. HORNER, M.Sc., M.I.E.E.

General situation.—An account of the electrical characteristics of the storm of 5 September may conveniently start at 0430 GMT when plots obtained by the Meteorological Office network of direction finders showed a concentration of sources of atmospherics on the French coast near Cherbourg. Later plots showed the storm proceeding northwards and crossing the English coast on a narrow front in the neighbourhood of the Isle of Wight at 1500 GMT. It then travelled towards London at a speed of about 15 knots, reaching the city about 1900 GMT, and finally died away some three hours later over Essex. Figure 1 shows the positions of the main electrical activity every two hours, derived from the direction-finding network, and also the echoes received on a radar equipment at the Meteorological Office, Kingsway, London, at 1600 and 2100 GMT. Both observation techniques indicated that there was other activity during this period, mainly to the north and reaching the area of the Wash at 2100 GMT.

Visual observations.—The London storm was under visual observation at the Radio Research Station, Slough, from 1845 to 2000 GMT, during which period the actual discharge channels of more than 100 flashes were seen. Many more flashes occurred, but were obscured by cloud or trees. The visual phenomena observed at Slough were of a most unusual nature. Most of the discharges seen almost certainly struck the ground, but the lowest parts were not visible. The discharges appeared to develop upwards and outwards from the cloud and spread across a clear sky, with extensive branching. This upward-branched type of discharge was well illustrated in photographs in the December 1958 issue of the *Meteorological Magazine*. The growth of the flashes was remarkably prolonged in many cases, the duration of the flash being several seconds. These long-duration flashes showed the most extensive branching, covering, on occasion, almost the whole sky. A large proportion of the

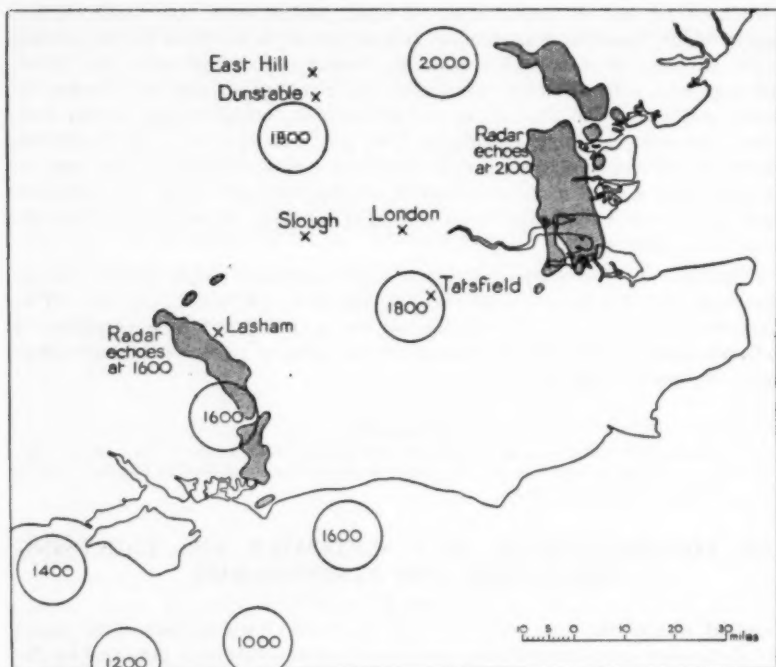


FIGURE 1—PROGRESS OF THUNDERSTORMS OF 5 SEPTEMBER 1958

The shaded areas give the positions of radar echoes, the crosses mark the locations of lightning flash counters and the circles show the approximate position of the major electrical activity at the times indicated but are not to be regarded as precise.

flashes which were clearly visible appeared to have more than one discharge channel to earth; in other cases there appeared to be only one channel to the ground but a branching upwards at a low altitude.

The unusually spectacular nature of the visual phenomena was no doubt partly due to the existence of a localized storm surrounded by clear air. It is possible that the complex type of air discharge occurs in many other storms but is obscured by cloud. On the other hand the storm was also unusual in other respects; the tops of the thunderclouds were reported as extending to a height in the region of 50,000 feet and a tornado occurred, a rare feature in English storms. The electrical characteristics, with long air discharges, appeared to be similar to those which are said to occur in tropical storms.

Number of lightning flashes.—It is natural to speculate on the number of flashes which were generated in this storm, and some relevant information exists from the records of several lightning flash counters. These instruments were of the type described in the *WMO Bulletin*,¹ and the sensitivity was such that they would be expected to trigger on a peak field of about 3 volts per metre, measured in the band 1–50 kilocycles per second. The locations of the counters are shown in Figure 1 and the hourly counts are shown in Table 1. A fuller account of the work with lightning flash counters has been published.²

TABLE I—HOURLY COUNTS OF LIGHTNING FLASHES, 5 SEPTEMBER 1958

GMT	Lasham	Slough	Tatsfield <i>Hourly counts</i>	London	East Hill	Dunstable
10-11	39	0	0	1	0	0
11-12	7	0	0	0	4	0
12-13	31	7	0	4	35	7
13-14	147	6	1	5	18	4
14-15	51	20	3	5	80	28
15-16	(300)	59	7	22	201	35
16-17	(2000)	(210)	22	61	411	59
17-18	(3000)	(240)	171	63	449	160
18-19	(2000)	(340)	2744	1690	2800	936
19-20	(2000)	260	2042	773	1568	262
20-21		45	38	30	783	95
21-22		16	9	36	518	
22-23		8	2	21	339	

The bracketed figures in the table are estimates based on examination of continuous pen records, where hourly visual readings were not taken. These records were too confused for accurate interpretation, but the estimates are probably within ± 30 per cent for Lasham and ± 10 per cent for Slough.

There is some evidence that the instruments differed somewhat in sensitivity. Lasham and East Hill appeared to be the most sensitive, probably owing to the open nature of the sites, and Dunstable was known to be in operation at slightly reduced sensitivity. Nevertheless the maximum hourly count was of the same order at all stations except Dunstable and Slough. The low Slough counts are no doubt due to the fact that this station alone did not experience the full force of the storm. Either the storm shown in Figure 1 split and passed either side of Slough or it passed wholly to the south and other storms approaching from the west affected Dunstable and East Hill.

Mention has been made of the fact that many of the flashes were of long duration, and some of these would be expected to trigger a counter two or three times. That this did happen could in fact be deduced from the character of the pen records. Nevertheless multiple counts would be expected to occur on only a small proportion of flashes, and it seems reasonable to deduce from Table I that the number of separate flashes was of the order of 2000 per hour. This is also confirmed by records of the radio noise which were taken at Slough; most individual atmospherics had a duration of about one second, and since the noise was almost continuous, the frequency of occurrence could not have been much less than 2000 per hour.

This figure may seem high in relation to the hundred discharges which were seen in an hour at Slough, but at this time the storm was twenty miles away and probably several miles across. It would be hardly surprising if the discharges seen were only those on the nearer fringes of the storm, particularly as the lowest 10,000 feet was obscured by trees. Also it is likely that many discharges were entirely within the cloud.

One feature of the storm was an apparent sudden reduction in electrical activity just before 2000 GMT. To illustrate this the counts in five-minute intervals at three stations have been plotted in Figure 2 from 1900 to 2100 GMT. The higher counts at Tatsfield (bracketed points) are rough figures from the pen records but are of the correct order. At all three stations there was a marked

decrease in counts between 1945 and 2000 GMT. The effect is most noticeable at Tatsfield where the decrease in storm activity coincided with the movement of the storm away from that station, but it is also quite pronounced at Slough which was 20 miles from the storm. At East Hill the counts did not decrease to the same extent as at Slough and Tatsfield, partly because there was some residual activity to the north and partly because the increased sensitivity would enable more distant flashes to be recorded. There seems little doubt that the electrical activity of the London storm decreased quite suddenly, and this is confirmed by some published records taken in Switzerland.³

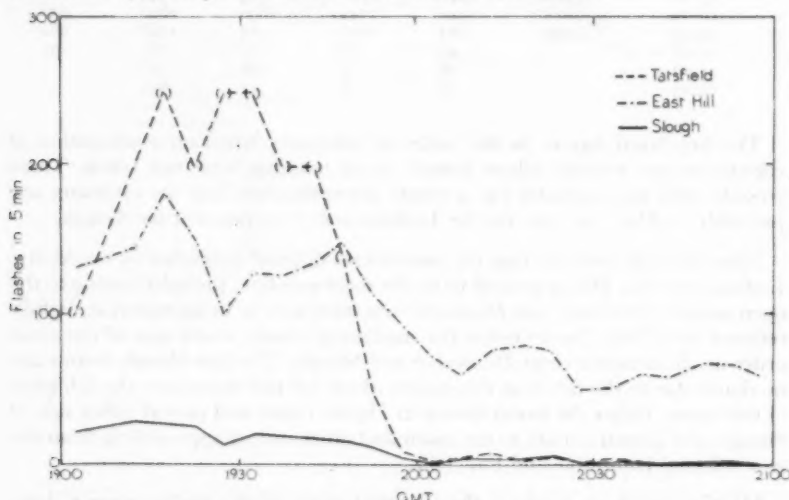
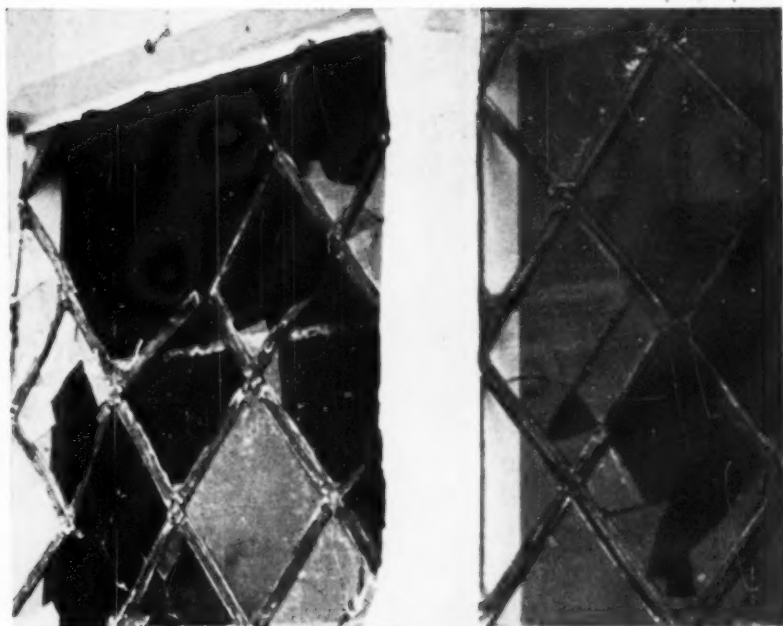


FIGURE 2—FLASHES RECORDED IN FIVE-MINUTE INTERVALS BETWEEN 1900 AND 2100 GMT

It is interesting to compare the rate of counting with that experienced in more usual storms. At the sensitivity used, a count of 30 per hour normally indicates that there are lightning flashes within or near audible range. In severe and widespread storms the hourly count may reach two or three hundred, and the highest hourly count recorded on any counter in 1958, excluding 5 September, was 400.

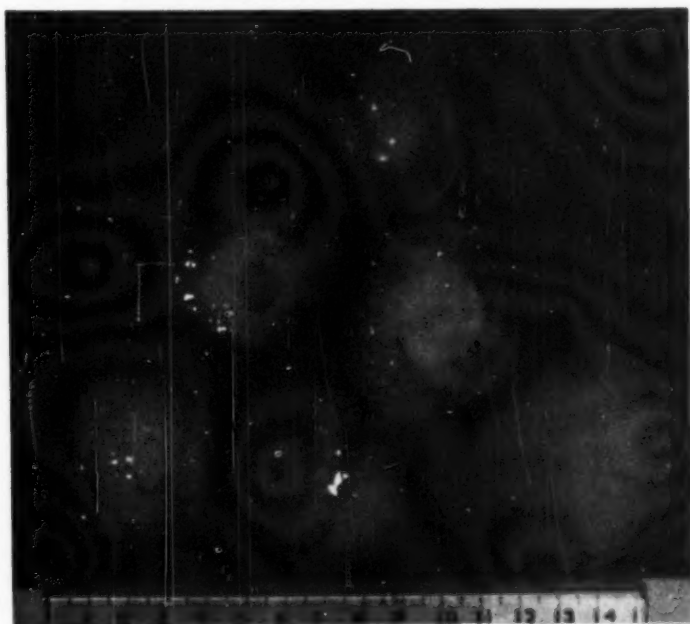
These observations were made as part of an investigation of atmospheric radio noise, and the atmospherics received on frequencies of 6, 10 and 45 kilocycles per second and 11 megacycles per second were recorded on magnetic tape. The analysis of these records has shown that the noise power received at Slough, during the storm, was of an order 1000 times greater than in average conditions for the time of day and year.

Acknowledgment.—The work described in the paper was carried out as part of the programme of the Radio Research Board and is published by permission of the Director of Radio Research of the Department of Scientific and Industrial Research. The radar photographs used in the work were taken by the late Mr. W. R. Hanson of the Meteorological Office and direction-finding data were also supplied by the Meteorological Office.



Photograph by W. C. Macklin

PLATE I—WINDOW PANES AND LEAD FRAMES OF THE BLUE SHIP INN, NEAR SLINFOLD
(WEST OF HORSHAM), AFTER THE HAILSTORM



Photograph by W. C. Macklin

PLATE II—HAILSTONES WHICH FELL AT OKEHURST FARM, WEST OF HORSHAM
The scale is graduated in centimetres. See p. 250



Photograph by G. F. W. Clapp

PLATE III—OAK TWISTED FROM GROUND NEAR BONWYCK'S PLACE FARM
(see p. 255)



Photograph by G. F. W. Clapp

PLATE IV—PINES TWISTED OFF ABOUT 20 FEET ABOVE GROUND LEVEL
(see p. 256)



Photograph by G. F. W. Clapp

PLATE V—CORRUGATED IRON WRAPPED AROUND BASE OF TREE

[see p. 255]

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DAYTIME FOG CLEARANCE AT EXETER AIRPORT

By W. E. SAUNDERS, B.Sc.

In an earlier paper¹ the time of clearance of radiation fog has been shown to vary, as might be expected, with the time of year and the vertical depth of fog. Cases where there was cloud cover during the day were excluded from that investigation. The effect of cloud cover during the night was dealt with in that paper,¹ and in a more recent paper,² where it was shown that the arrival of stratocumulus cloud during the night leads to fog clearance unless initially the soil-to-air temperature difference is very small.

The present note deals with two aspects of daytime fog clearance during the winter months. Firstly, the effect of the vertical depth of fog is considered in more detail, and secondly it is shown that the presence of a sheet of low or medium cloud overhead normally hastens the fog clearance. The question of what depth of fog is represented by a report of "sky obscured" is dealt with in an Appendix (p. 263).

This investigation was restricted to the months November to February, for the years 1950-59. All cases in which there was radiation fog at Exeter in the period 0500-0700 GMT (hereafter referred to as the "initial time") were included for examination. Occasions on which a freshening wind appeared to affect the fog clearance time were excluded. From the remainder those cases were extracted where either there was little or no cloud above the fog between the initial time and the time of fog clearance, or else it was cloudy (7/8-8/8) with low or medium cloud during that period. This separation meant the omission of a small number of cases in which the cloud cover varied during the period. The results have been tabulated to bring out the essential differences.

TABLE I—FOG CLEARANCE AT EXETER ON CLEAR SKY AND LIGHT WIND
OCCASIONS

Occasions of little or no cloud apart from broken cirrus			
		Sky visible at initial time	Sky obscured at initial time
Total number of cases	...	14	11
Cases when fog cleared during day	...	14	5
Cases when fog failed to clear	...	0	6
Time of clearance	...	0800-1130 GMT	1200-1430 GMT
Visibility after fog cleared	...	5-30 n.m.	1300-2400 yd
Time fog re-formed	...	Not before 2100 GMT	1530-1730 GMT

In Table I, in the cases included in the right-hand column, it was, of course, inferred that there was no cloud above the fog. There was no cloud before or after the period in which the sky was reported as obscured.

Table I re-emphasizes a point mentioned in the previous article,¹ that the vertical depth of fog in the early morning, even when measured crudely according as the sky was or was not obscured by fog, is of great importance in

determining the time of fog clearance. The "sky visible" cases cleared during the forenoon (11 out of 14 cleared between 0830 and 1000 GMT), and the fog cleared completely to give good afternoon visibility. Fog did not re-form before 2100 GMT. In the "sky obscured" cases fog persisted all day on more than half the occasions. When it did clear, visibility only improved to rather misty conditions after midday, and thick fog re-formed in the dusk period. Probably the physical difference between the two types of case was that in the former the temperature inversion near the ground had time to break down, and in the latter it failed to do so. The clear-cut division of types shown in Table I only applied to those occasions which could be definitely classified as either clear sky or cloudy. In the cases which were excluded from Table I because the cloud cover was variable, the behaviour as regards fog clearance was also variable, the fog dispersing and re-forming during the daytime in some of them.

The results given in Table I may be of interest elsewhere, but it must be borne in mind that Exeter is a rural site and the fog is free from heavy pollution. On sites near large built-up areas the out-pouring of smoke at 0800-0900 hours on weekdays would no doubt off-set the fact that the fog was thin at 0500-0700 hours, and the separation of cases as in Table I would probably be of no value on such sites.

Table I strengthens a conclusion already expressed in the earlier paper,¹ that there is a considerable need for a means of measuring the depth of fog at airfields (other than by aircraft ascents), so that use can be made of the actual depth of fog, instead of whether or not the sky was obscured, in forecasting clearance times.

The cloudy occasions were separated according as the sky was visible at the initial time, and low or medium cloud cover reported, or the sky obscured at the initial time and cloud reported when the sky became visible. The results are given in Table II.

TABLE II—FOG CLEARANCE AT EXETER ON CLOUDY AND LIGHT WIND OCCASIONS

			Occasions of cloud cover	
			Sky visible at initial time; cloudy	Sky obscured at initial time; cloudy when sky became visible
Total number of cases	...	...	21	40
Cases when fog cleared during day...	...	...	21	40
Time of fog clearance	...	...	0600-1100 GMT	In cases where arrival of cloud could be timed, time interval from cloud arrival to fog clearance varied from 30 min to 3 hr

Comparison of Table II with the right-hand column in Table I shows that the presence of a cloud sheet during winter renders fog clearance more likely. The cases which are strictly comparable are those in the left-hand columns of Tables I and II. In both of these the fog was thin enough initially for a "sky visible" report, and the significant difference was in the cloud cover above the fog. In the Table I cases the time of fog clearance was on average 1 hour 50 minutes after sunrise. The corresponding interval for Table II was 36 minutes. It appears therefore that, in general, at a ruraly-sited airfield in southern England, the normal soil-to-air temperature difference in winter is such that fog will clear rather more than one hour earlier if there is low or

medium cloud overhead than under clear-sky conditions. This implies that the heat flux from ground to air more than offsets the loss of insolation due to the cloud cover.

The results given in this paper, and in the two previous papers,^{1, 2} stress the importance of cloud cover in fog forecasting. It seems very probable that the cloud cover is much more significant in fog forecasting than it is in general visibility forecasting, where in the majority of cases, the visibility is above the fog range. This suggests that in objective methods for forecasting visibility (for example, that described recently by Freeman³) increased accuracy in forecasts of visibility in and near fog limits would result from taking more account of the cloud amount. This might best be accomplished by using a forecast cloud amount instead of the actual cloud reported at the beginning of the forecast period.

Appendix

The depth of fog reported as "sky obscured"

A study of the variation with time of the height of fog top was made by Stewart,⁴ using Cardington data. This showed that, in most cases, the depth of fog has reached a static value by a time within the period 0500-0700 GMT taken as the "initial time" in the work described in the present paper. This is rather encouraging because it supports the view that the fog depth at that time in the morning can be taken as representative for use in forecasting the clearance time.

The Cardington data was examined to see what depth of fog was reported at times when the observer on the ground reported "sky obscured". The height of fog top was measured, in the case of shallow fog, by a fog density indicator or by direct measurement from a 60-foot tower. In all other cases it was deduced from the temperature and humidity profiles (but usually only to the nearest 250 feet, according to Stewart). The results of this comparison are given in Table III.

TABLE III—DEPTH OF FOG ASSOCIATED WITH REPORTS OF SKY VISIBLE OR OBSCURED AT CARDINGTON

Depth of fog feet	Surface report "sky visible" number of cases	"Sky obscured"
0-100	42	0
101-200	8	6
201-300	6	3
301-400	2	5
401-500	1	10
Over 500	0	37

Table III suggests that, allowing for probable errors in estimating the heights of the fog tops, a "sky visible" fog is not more than about 300 feet deep.

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WORLD METEOROLOGICAL ORGANIZATION

The twelfth session of the Executive Committee

By C. W. G. DAKING, B.Sc.

The first session of the Executive Committee during the Third Financial Period (1960-63) took place in the new permanent building of the World Meteorological Organization from 27 June to 15 July 1960. There was a full attendance of Members, now eighteen in number. In addition, Dr. A. Silva de Sousa, President of the Commission for Aeronautical Meteorology, was present to submit a report on the work of that Commission, particularly concerning its joint session with the Meteorological Division of the International Civil Aviation Organization which was held in Montreal in September last year. Mr. P. D. McTaggart Cowan, Director of the Canadian Meteorological Service, was elected to fill the vacancy caused by the retirement of Dr. A. Thomson in September 1959.

The session was, as usual, a busy one but its business was facilitated by the excellence of the accommodation, the rapidity with which working papers were produced and by the provision of simultaneous translation for each of the working committees, as well as for the plenary meetings.

Under general questions by far the most important was the beginning of a study of the Convention as instructed by Third Congress. After an examination of those Articles which most require revision, the Committee decided to establish a working group to study the whole Convention and to report to the thirteenth session of the Executive Committee. The Director-General agreed to serve as a member of this group. Other general matters discussed included procedures for the implementation of joint support schemes, working arrangements with other inter-governmental organizations and with non-governmental organizations and the representation of WMO on permanent committees of other international organizations. In technical matters, the Committee gave particular attention to a recommendation from the International Geophysical Committee to the effect that a Permanent Service in meteorology should be set up by the Federation of Astronomical and Geophysical Permanent Services in the WMO Headquarters when the IGY Meteorological Data Centre is closed. The desirability of making meteorological data available in a convenient form for research workers was recognized but doubts were expressed as to whether the proposed Permanent Service would make a substantial contribution towards solving this problem. In this connexion, the steps taken by the Secretary-General to prepare a catalogue showing how data may be obtained for research purposes were noted with satisfaction and it was decided that the results of this inquiry amongst Members should be studied before a final decision to create a Permanent Service was taken. Consequently, the Committee decided to form a working group on meteorological data for research to review the matter and to make recommendations regarding future action to be taken by WMO.

A great deal of time was needed to study the two volumes of the report of the second session of the Commission for Aeronautical Meteorology, with its consequential repercussions on Volume II Chapter 12 of the Technical Regulations of the Organization.

The Committee also considered questions arising from the introduction of commercial jet aircraft and noted that it would soon be possible to publish a

technical note on "Techniques of analysis and forecasting for high-level winds and temperatures" which had been prepared as a result of action taken at the tenth session of the Executive Committee.

The preparation and publication of an International Meteorological Vocabulary gave rise to much discussion, as a marked division of views on this question was evident. Some Members evinced little interest in the project while others regarded this publication as of paramount interest, particularly for countries whose mother tongues were not amongst the working languages of the Organization, namely, English and French. It was decided that the existing material should be divided according to the different main fields of meteorology and that the Presidents of the Commission for Synoptic Meteorology, the Commission for Aerology, the Commission for Instruments and Methods of Observation and the Commission for Climatology should be asked to nominate experts to serve on a working group to check and finalize the definitions falling in their respective fields. It was also decided to request the Permanent Representatives of France and the United Kingdom to nominate one expert each to participate in this work as editors of the text in their respective languages.

A further step was taken towards the organizing of an international warning system for sea waves of seismic origin (Tsunami) and it was also agreed to include in the WMO programme the international aspects of avalanche warnings.

The fifth International Meteorological Organization Prize was awarded to Professor J. Van Mieghem of the Royal Meteorological Institute of Belgium. In making this award the Committee, no doubt, took into account the outstanding contributions to meteorology which Professor Van Mieghem made in preparation for and during the course of the IGY and IGC (1959). In addition, Professor Van Mieghem has been Vice-President and President of the Commission for Aerology of WMO.

The high light of the session was the combined ceremony to celebrate the tenth anniversary of WMO and the inauguration of the new Headquarters building. This took place on 12 July 1960 in the presence of representatives of the Swiss Federal Government and of the Canton of Geneva and many members of the Diplomatic Corps of Geneva. A special edition of the *WMO Bulletin* and a booklet entitled *WMO—The First Ten Years* were issued in honour of the occasion. Many Members have presented contributions to the furnishings and decorations of the new building and, in due course, a booklet containing a detailed description of the building and of the gifts presented will be issued. The gift of the United Kingdom consisted of a set of tables in walnut, and an armchair and twenty-two small chairs of most attractive design upholstered in red leather—it constitutes the main furnishings of the small conference room which was used during the twelfth session of the Executive Committee by the Committee on Administrative and Financial Questions. The Director-General participated in the deliberations of this Committee both as a member and as a part-time chairman and can vouch for the comfort of the chairs.

The WMO Secretariat are indeed fortunate to have such a tasteful, light and airy building to work in, but after many years of enduring huddled accommodation, albeit superior wooden ones, one cannot begrudge their transportation to the "palace" which is now their home. Every visit to sessions of the Executive

Committee or Congress impresses upon one the excellent work carried out by Mr. D. A. Davies and his staff and the devotion to the advancement of meteorology in the international field which all those with whom one comes into contact seem to possess.

METEOROLOGICAL OFFICE DISCUSSION

Forecasting high-level winds and temperatures

The Meteorological Office discussion at the Royal Society of Arts on Monday 21 March 1960 was on the subject of "Forecasting high-level winds and temperatures". Dr. J. M. Stagg was in the Chair and the opening speakers were Mr. C. L. Hawson and Mr. R. J. Ogden.

In his opening statement Mr. Hawson pointed out that the methods of observation, analysis, and forecasting are essentially the same in principle, that is, to draw 1000-millibar contours derived from mean-sea-level pressures, together with a series of thickness values between standard isobaric surfaces which are successively added to the 1000-millibar contours to derive the higher contour fields. He dealt in turn with the three factors which change thickness values: advection, non-adiabatic heating, and vertical motion, and discussed some features of the 500-300 and 300-200-millibar thickness patterns. Turning to the problems at 100 millibars, he said that persistence often gives a good forecast at this level especially in summer and the major problem is one of analysis amid the chaos of the 100-millibar height observations. He said Dr. Caton and himself had developed a technique to explore the systematic differences between the 100-millibar geopotential height observations of different sondes and to estimate the standard deviation of their random errors. Observed 100-millibar geopotential heights yield misleading contour gradients, and the method of analysis recommended at this level is to use observed winds to derive contour gradients, and groups of corrected contour height observations (over areas of several hundred miles radius or spaced in time) to determine local contour values; the two procedures generally complement one another. Mr. Hawson added that the 100-millibar chart is a great help in assessing the accuracy of geopotential height observations on the 200- and 300-millibar charts. He concluded with a discussion on some features of the 100-millibar charts, presented slides to illustrate examples of 1000-, 300-, and 100-millibar flow in summer, and in winter, together with changes experienced in twenty-four hours, and suggested that an attempt to forecast the 200-millibar field by building down from 100 millibars is well worth exploring.

Mr. Ogden outlined the wind and temperature requirements of commercial turbine-engined aircraft: forecasts up to 36 hours, over an area up to 4500 nautical miles radius, for all levels up to approximately 200 (or 150) millibars, with an accuracy of $\pm 3^{\circ}\text{C}$ and ± 15 knots or 20 per cent of verifying equivalent headwind. He then sketched the relevant parts of the London Airport routine. Two forecasters are employed, the gridding process, invaluable as it is in chart construction, is used as a tool not as a strait jacket, and gridding at 200 millibars is only mandatory over the oceanic areas. All forecast charts issued at London Airport are radially composite from London, assuming a ground speed of 300 knots, and isotachs are entered in the forecast charts. The isotachs are intended to provide actual rather than geostrophic winds and Mr. Ogden emphasized that the difference between the two can be 40 or 50 knots. Spot

values for forecast temperatures are placed at convenient points along standard tracks. He showed a typical 300-millibar prontour isotach chart and then discussed difficulties of interpolation between standard pressure levels and the associated problems of mapping and forecasting the tropopause surface and its temperature. He said tropopause maximum centres (above 300 millibars) seem to be aligned over warm pools in the 500-300-millibar thickness pattern, whilst tropopause minimum centres are vertically aligned below warm pools in the 300-200-millibar thickness pattern. He then gave a survey of the techniques for forecasting wind speed at intermediate levels suggested by Reiter,¹ Harmantas and Simplicio,² and Graham,³ using the work of Endlich *et alii*.^{4, 5}

Mr. Ogden concluded by saying the idea of isoshears is so attractive that a serious trial of this should be made, seeking an amenable parameter to relate to shear, and he suggested the 500-300-millibar thickness gradient for this purpose. He was certain we have plenty of work still to do.

Mr. N. E. Davis spoke of the promising results he had achieved in experimental attempts to forecast the 200-millibar chart building down from 100 millibars through the 200-100-millibar thickness field, and showed slides of examples.

Mr. F. H. Bushby said that recent numerical forecasts showed wind errors at 500 millibars comparable with those of the Central Forecasting Office (CFO), but those at 200 millibars were slightly greater.

Mr. E. Chambers (BOAC) said that, with supersonic aircraft, forecasts at or above 60 millibars would probably be required in future. He also said that although satisfied with the present forecasting arrangements the civil airlines would prefer a fixed-time chart for the first 2000 miles of a route with another chart beyond.

Dr. J. M. Stagg asked which other countries drew composite forecast charts for upper levels. Mr. Ogden replied in his experience only the United States did so.

Mr. J. Harding called attention to the increasing importance of machine-produced prontours. He understood that such features as jet streams tend to be smoothed out in such prontours, and that subjective allowance must be made for this at outstations. He thought all forecast charts should be regarded as "initial guess" fields to be corrected as later information becomes available, but that at any forecast office relying entirely on CFO's prontours there is a need for as much detail as possible in the actual prontours.

Mr. B. C. V. Oddie commented on the interest in upper air analysis and forecasting, doubted whether complete success by computer was just around the corner, and thought current methods should be mastered by all who had the chance to do so.

Mr. J. S. Sawyer emphasized that present techniques of upper air forecasting are very economical. To do all this work by machine would be very expensive and there would still be a need for forecasters to interpret the forecast charts. He thought the civil aviation authorities might be asking for greater accuracy in forecasting upper winds and temperatures than is at present scientifically acceptable.

Mr. C. J. M. Aanensen spoke of Royal Air Force requirements, pointing out that although jet bombers fly high over long distances there is no requirement to cut fuel to a minimum in order to carry maximum payload. In general, wind

and temperature forecasts are required for specific routes and heights. At Bawtry, where only one forecaster has to deal with both surface and upper air, upper air charting and forecasting techniques are streamlined to a very considerable extent; charts for 300, 200, 150, and 100 millibars are drawn up directly and no gridding is done.

Mr. D. G. Harley said that at Prestwick they like the idea of showing variations above 300 millibars by charts of maximum wind level and shear. He pointed out that charts of this type are economical of effort and easily used by the operator.

Mr. F. A. Sharp asked if isotachs could be added to the CFO prontours.

Dr. J. M. Stagg, in closing the discussion, said the present aim should be to improve existing techniques.

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OFFICIAL PUBLICATION

The following publication has recently been issued:

SCIENTIFIC PAPER

No. 2—*Conservation of vorticity at 100 millibars*. By J. R. Probert-Jones, B.A.

Five sequences of 100-millibar charts, each sequence covering three to five days, were redrawn so that the change in each 12-hour period implied a divergence of less than $2 \times 10^{-6} \text{sec}^{-1}$, which is negligible on the synoptic scale. The redrawn sequences were smoother in time with respect to height and significantly smoother with respect to wind than the original set. The observed winds were fitted better by the redrawn sequences, and although the heights were fitted better by the original sequences, it is indicated that the fit of the original sequences was too good. It is concluded that the evidence supported the hypothesis of approximate non-divergent flow at the 100-millibar level.

REVIEWS

Calculation of the brightness of light in the case of anisotropic scattering. Transactions (Trudy) of the Institute of Atmospheric Physics No. 1, by E. M. Feigelson, M. S. Malkevich, S. Ya Kogan, T. D. Koronotova, K. S. Glazova and M. A. Kuznetsova. 10 in. \times 6½ in., pp. 101, illus., Consultants Bureau Enterprises, Inc., 227 West 17th Street, New York 11, New York, 1960. Price: \$8.00.

Consultants Bureau, Inc. of New York were one of the first commercial translating agencies to undertake the publication of translations of Russian scientific books and papers.

The volume under review is a translation of the first number of the Transactions of the Institute of Atmospheric Physics of the U.S.S.R. Academy of Sciences. The original Russian paper was published in 1958. The paper contains 56 pages of highly mathematical text, 36 figures and 45 pages of tables. The translation is in good scientific style with accurate English meteorological and mathematical

terminology. The title of the original was translated in the Meteorological Office Library as "Computation of the brightness of daylight illumination in the atmosphere under anisotropic scattering", which is more informative of the contents of the paper than the more literal translation used by Consultants Bureau.

The quality of the reproduction, by photolithography from typescript, is also of high quality. The mathematical formulae, figures and tables have clearly been produced by cutting them from copies of the original and fixing them at the right places in the English typescript before it was photographed, care being taken to replace Russian legends and headings by English equivalents.

The copy is bound in hard covers. The price at \$8.00 is not high for such a very specialized publication which would not be expected to sell in large numbers.

G. A. BULL

Dynamics of climate, edited by Richard L. Pfeffer. 9 in. \times 6 in., pp. xv + 137, illus., Pergamon Press, Oxford, 1960. Price: 35s.

The sub-title, "The proceedings of a conference on the application of numerical integration techniques to the problem of the general circulation held October 26-28, 1955," tells much more what this book is about than the title itself, which would be misleading to a prospective buyer expecting to find an integrated dynamical account of climate. But, then, we know that such an account is not yet possible. The first question which naturally arises is whether it is worthwhile to publish the proceedings of a conference held more than four years ago. Two reasons for publication are given in the editor's preface, "to organise the essential ideas within a single volume, together with the pertinent discussion material, in an effort to present a somewhat unified treatment of the subject matter, and secondly, to record for historical purposes the status of thinking at the beginning of what promises to be a new and important era in the science of meteorology." It should be noted at once that the conference was held at Princeton and was essentially domestic to the United States, as the list of participants shows. The "status of thinking" represented in this book is therefore that of a special group, and is not international.

The conference report is in five sections. The introductory talks are briefly reported and are followed by a section of seven short papers on numerical methods and related topics, where "papers" is a generic term since the summaries of what the speakers said have been reconstructed from notes and tape-recordings taken at the conference. Here we find what was probably Phillips's first report of his numerical experiment on the general circulation, which he later wrote up as the prize-winning essay published in the *Quarterly Journal of the Royal Meteorological Society*; the latter is the preferable reference, and generally the published papers to be found in meteorological journals are to be preferred to the shortened versions given in this book. The paper by Charney is valuable in that it puts into print some of the most pertinent questions that have to be answered in order to construct a dynamical model which will explain the features of the general circulation. While such a list may well frighten off the faint-hearted (and why not?) it does show the integration of physical processes that requires explanation and that there is no discovery, just around the corner, which will revolutionize the solution to the problem. Eliassen's remarks in this section are also noteworthy and not to be found elsewhere, as far as I

know. The other papers, and indeed all the papers in the book, are interesting but can be found in more detail elsewhere.

The third section contains eight papers on other studies of the general circulation and climatic change. The selection of topics was, no doubt, a reflection of who was available to attend the conference and there is much less coherence between the papers in this than in the previous section; not expectedly since the range is so much larger. Nor is it very apparent how this section complements the first except for the discussions of the experiments on rotating fluids.

The fourth section contains two papers on radiation studies. Kaplan has certainly carried his work much further than the chrysalis stage described here. The fifth section reports, in a very shortened form, the discussions that took place. It is of more interest than the remaining sections and it is a pity that it is so abbreviated as to be almost incomprehensible in places.

The proceedings of a conference cannot fail to be interesting and this is not an exception. On the other hand, they cannot give a unified picture of the subject and are not a substitute for the original fuller papers published elsewhere. To be valuable the publication must be rapid, so as not to date; in this case the lapse of over four years has proved too long and there are now better sources for information on new ideas.

The production and printing are up to Pergamon's usual standard and the only slight criticism is that von Neumann's photograph, which appears as a frontispiece, does not bear his name.

E. KNIGHTING

General meteorology, by H. R. Byers. 9 in. \times 6 in., pp. x+540, *illus.*, McGraw-Hill Publishing Co. Ltd., McGraw-Hill House, 95 Farringdon Street, London, E.C.4. 1959. Price: £3 14s.

Any young meteorologist who worked through this text would be well equipped for his profession. He would have a good idea of the part radiation plays, enough thermodynamics, an understanding of how the rotating earth affects the dynamics, and a knowledge of the structure in depth of cyclones and anticyclones. He would be aware of the special problems of tropical meteorology and be in possession of almost up-to-date knowledge about tropical cyclones. The basis of the use of electronic computers to perform step-by-step integrations of the equation for the change in height of a contour surface would be familiar to him. He would be well aware of the physics of condensation and evaporation, and have the benefit of the author's first-hand knowledge of the post-war Thunderstorm Project in Ohio. And from the last two chapters he would get a fair idea about fog, and an acquaintance with the language of turbulence.

Having provided so much the author may be excused some inaccuracies, but there are some wrong impressions given from which the student may expect to be spared.

For example, it is surely not right to give the impression (p. 302) that departures from geostrophic motion of fronts are due mainly to surface friction. Over the British Isles and the eastern Atlantic, at any rate, warm fronts are slowed down by the ageostrophic motion of the cold air. Most cold fronts progress at, or a little above, the geostrophic rate despite frictional retardation

of the lowest layers. In fact the only reference in the very full index to ageostrophic motion is in connexion with flux of momentum.

Further, a student would very likely from the remarks on page 230 go away with the idea that thickness patterns (above 500 millibars, anyway) were usually in phase with contour patterns. The phase relationships in the most significant weather changes he would afterwards encounter would surely cause him to think that he had been somewhat misled.

Twice (on pp. 285 and 370) the remark is made that some of the heaviest rainfall of the Indian Monsoon occurs in the convergence zone between the air from the Indian Ocean and that from the Arabian Desert and the Arabian Sea. I am sure from this and a look at an atlas that any student would conclude that there was a band of heavy rain across the northern part of the Indian Ocean. In fact, air from the Indian Ocean reaches the south coast of Arabia east of 50°E as a south-south-westerly current in July and August so that any convergence zone must lie over the Arabian Desert itself.

If some suggested mechanism (for example, friction and fronts, convergence and rainfall) appears to explain an occurrence then the student can be forgiven for thinking it is the whole story and using it without the qualifications the author would undoubtedly have in mind in giving it. It is surely a great mistake in meteorology to encourage the student to rely overmuch on theoretical ideas. It is quite surprising how long it can take for the necessarily somewhat incomplete and rarely incontrovertible facts about the atmosphere to exert their true weight against ideas gained from the textbook.

Nevertheless this is a book which can be thoroughly recommended to the young professional meteorologist.

M. K. MILES

[The delay, in no way due to the reviewer, in publishing a review of *General meteorology*, is regretted.—Ed. M.M.]

Pflanze und Strahlung (Probleme der Bioklimatologie Bd. 5), by F. Sauberer and O. Härtel. 9 in. × 6½ in., pp. ix + 268, illus., Akademische Verlagsgesellschaft Geest & Portig K.-G., Leipzig, 1959. Price: D.M. 29.50.

This volume is part of a series of publications under the general title "Problems of bioclimatology". One of the authors is a meteorologist specializing in bioclimatology and the other is a plant physiologist. In their view, a good deal of the work so far carried out on the effect of radiation on plants is faulty or incomplete and the time is ripe for a comprehensive review of the state of knowledge. The book which they have produced reflects very clearly the division of interest to which they refer and in a sense it may be regarded as two books bound together for convenience.

After a short section on radiation in general, there is a detailed discussion on natural fields of radiation, dealing in turn with the short-wave, long-wave and total radiation balance. Whilst there does not appear to be anything fundamentally new, some of the supporting tables and diagrams are of interest in providing data of direct practical value, for example, Tables 13 and 14a which concern solar radiation on slopes and walls with various orientations. The following section deals with heat exchange and here, in discussing the effects on leaves, the first mention is made of plants, some third of the way through the book.

From this point, the emphasis is more on plant-life and the ways in which it is affected by radiation. This involves the discussion of radiation exchange for individual parts of plants, for whole plants and for stands of plants. Because of the relations between light and many aspects of plant development, most of the examples quoted here are concerned only with the visible spectrum. One point of interest which is brought out by many diagrams is the dependence of the biological consequences of radiation on the spectral distribution of the latter; for example, certain wavelengths of light can induce germination, whilst others will impede it in the same plant.

There is a comprehensive bibliography with references largely, but not entirely, to publications in German; the author and subject indexes are useful. The text is divided under headings and sub-headings and this makes the book easy to use. There are 99 tables and 82 diagrams and anyone with only a slight knowledge of German would profit by examining these, particularly as they are very clear and informative. This is undoubtedly a useful reference book and is no doubt welcome in Germany where there is more organized activity in bioclimatology than in this country. A similar book in English would be equally welcome here.

W. H. HOGG

Radar meteorology, by L. J. Battan. 9½ in. × 6 in., pp. xi + 161, *illus.*, University of Chicago Press, U.S.A. (agents: Cambridge University Press, London), 1959. Price: £2 5s.

This is the first book to have been published dealing solely with radar meteorology. It is well written and a useful book of reference, but also makes interesting general reading. The author has been especially active in research in radar meteorology as a member of the cloud physics research group at the University of Chicago, and is now a Professor of Meteorology at the University of Arizona.

The first three chapters deal with the propagation of electro-magnetic waves through the atmosphere at radar wavelengths, with enough simple mathematical theory to lead to the conception of the modified index of refraction, which is valuable in defining "standard refraction" and ducting conditions. The illustration chosen of ground ducting is an unusual and interesting one. It is of a low-level duct formed by the cold air spreading out from a large thunderstorm mass (presumably over very wet ground). This is apparently an important source of ducting conditions in America, but your reviewer is convinced that it is extremely rare in England. He has not seen a single case of it in several years of observation.

The next three chapters give an outline of the theory of scattering and attenuation by raindrops and ice spheres, and give present ideas of scattering by melting ice spheres and non-spherical particles. Unfortunately there is as yet no adequate theory of scattering from snowflakes, nor real knowledge of their form and distribution aloft.

The remaining nine chapters will be of most interest to the general reader, since they deal with the practical uses of radar to the meteorologist. Included is a down-to-earth assessment of radar as applied to quantitative precipitation measurement and to hydrology. Too many workers on this problem have erred on the side of optimism. A number of pages are devoted to problems of locating and forecasting the movement of storms, especially of hurricanes and tornadoes.

The urgent need to add to this knowledge has determined the location of a large proportion of the weather radars in the United States. The largest individual section of the book is on the uses of radar in cloud physics research, summarizing more than thirty scientific papers, and there are chapters on mesometeorology and larger-scale weather systems.

A particularly valuable chapter deals with airborne radar in flight operations, in which the author makes out a strong case for vertical-scanning airborne equipment. He gives photographs taken with an experimental equipment which not only define thunderstorm tops ahead of the aircraft and their relation to flight level, but also show ground contours beneath the flight path.

Final chapters are on radar "angels" and on special instrumental techniques. That on "angels" has well-chosen illustrations, but the author finds himself summarizing widely divergent theories as to their origin. This perhaps illustrates a slight fault in an otherwise excellent book, that the reader is given a non-committal summary where in many cases a critical survey would have been of greater value.

It was to be expected that a book on radar meteorology would be expensive because of inevitably limited sales, but to offset this it is lavishly illustrated, and the paper and type-setting are of fine quality. More than 180 papers are referenced in footnotes, and there are author and subject indexes.

W. G. HARPER

Die Sommerniederschläge Mitteleuropas in den letzten 1½ Jahrhunderten und ihre Beziehungen zum Sonnenfleckenzyklus, by F. Baur. 9 in. \times 6½ in., pp. iv+80, illus., Akademische Verlagsgesellschaft Geest & Portig K.-G., Leipzig, 1959. Price: 9 D.M.

The author describes the aims of this booklet as follows: to draw up an (as far as possible) homogeneous table of the summer rainfall of central Europe for each summer from the beginning of the nineteenth century, to use this table to extend his investigations of the dependence (*sic*) of the general character of the weather (*Witterung*) on the sunspot cycle and thereby to give greater certainty to rules previously derived from shorter observation series. χ^2 tests are used to establish the reality of the associations suggested. The observational material reveals a tendency for dry summers in central Europe just two years before both extremes of the 11-year sunspot cycle and also in the second summer after the sunspot maximum—that is, the dry summer tendency has two to three peaks in each sunspot cycle. No fourth peak of dry summers (such as might, on grounds of symmetry, be looked for in the second summer after sunspot minimum) could stand out because of the asymmetry of the normal sunspot cycle—the next sunspot maximum generally follows too soon after the minimum for two peaks of dry summers to be sandwiched in between.

Baur stresses that in the large-scale circulation patterns of temperate and higher latitudes, including those which govern European summers, no 11-year period is obvious. Elsewhere he has recently demonstrated that even the growth rings of pine trees in the Erzgebirge, analysed from 1763 to 1941, suggest rather a subdivision of the sunspot cycle into two to three shorter periods.

The explanation proposed is that the general circulation of the atmosphere is influenced not so much by the corpuscular emissions and short-wave radiation

from the outermost layers of the sun (chromosphere), which produce the 11-year period in magnetic phenomena, as by longer-wave radiation emitted from deeper in the sun (photosphere). Baur suggests that a proportion η of the photosphere radiation P is absorbed in the chromosphere and radiated back towards the sun's interior, so that the amount A escaping into space and available to affect the Earth is:

$$A = P(1 - \eta).$$

Both P and η are supposed to increase with the sunspot number. The simplest assumptions give a parabolic form to the curve of A with maximum values of emitted energy midway between the extremes of sunspot number. It is admitted that solar physics has so far failed to confirm (or refute) these assumptions and that the only directly observed evidence of increased receipt of solar energy at certain phases of the sunspot cycle is in the ultra-violet and production of ozone. To this Baur pleads the urgency of constant monitoring of total solar radiation by means of artificial earth-satellite observations and neatly adds that this objective is "a thousand times more important than photographing the back of the moon".

Baur suggests reasons why at times of maximum solar energy (that is, at intermediate phases of the sunspot cycle according to the foregoing proposition) the subtropical high-pressure belts in both hemispheres should tend to be displaced polewards and for a simultaneous tendency for development of summer anticyclones over the polar regions. His theory might explain a double wave of such atmospheric circulation phenomena within the 11-year sunspot cycle but not a triple wave, unless this is to be seen as an accidental impression caused by the irregularities of length and course of development of different sunspot cycles.

The author is aware of the gaps in available knowledge and understanding of both the solar processes and (terrestrial) atmospheric mechanisms here involved. No doubt some of his arguments will be received with corresponding scepticism in various quarters. Some explanation is needed for the fact that the *position* of the given summer within the sunspot cycle seems to matter far more than the sunspot number: this position is perhaps best expressed as the ratio of the time elapsed since the last sunspot extreme to the time to go before the next extreme, thus standardizing the phase in spite of the somewhat variable length of the sunspot cycles. No reservations about these difficulties or any other aspect of the presentation can, however, gainsay Baur's impressive array of evidence that associations with the sunspot cycle play an important part in Europe's summer weather.

Account must of course be taken of any anomalies in the thermal condition of the Earth's surface as a legacy from the preceding winter, though Baur believes these play only a secondary role. There is some special interest in the explanation suggested for the six wet summers in succession 1953-58 within the present highly abnormal sunspot cycle.

Baur has certainly shown that no institution concerned with long-range weather forecasting can afford to ignore possible variations in the impact of solar energy and associations with the solar cycle. This little book will be an essential reference in such institutions both for the long series of data presented and for the minute description which Baur gives of the methods he has used.

H. H. LAMB

Understanding weather, by O. G. Sutton. 7 in. \times 4½ in., pp. 215, *illus.*, Penguin Books Ltd., Harmondsworth, Middx., 1960. Price: 3s. 6d.

The author makes no claim that this little book provides a systematic account of meteorology yet the scope of its somewhat unorthodox approach to, and its treatment of, the subject is quite remarkably wide.

Beginning with an account of the structure of the atmosphere up to a height of 80 kilometres (below which, it is pointed out, the interests of meteorology are presently confined), the broader aspects of the subject are then examined succinctly under the heading of the Atmospheric Engine. In this chapter, a summary is given of the radiation balance followed by a discussion of the factors determining air movement, leading to an account of the development of investigations into the general circulation of the atmosphere. In the following chapter on Winds, Clouds and Rain, the terms geostrophic, gradient and thermal wind are explained: the description of the tornado provides an opportunity for defining and discussing instability, as does the hurricane for showing the development of a vortex in a pressure wave and the jet stream for illustrating the thermal wind: and the account of clouds, rain and rainmaking is preceded by paragraphs on the process of condensation, condensation nuclei and supercooling. The fact that all this with 12 diagrams, is contained within 67 Pelican pages may suggest that the treatment is either superficial or is designed for the initiated. On the contrary it is uncommonly thorough considering the inevitable compression, and the arguments are so clearly and logically developed (in spite of the apparent disorder in the sequence of topics) that their understanding should present no difficulty to the reader possessing a knowledge of elementary physics and mechanics.

Apart from an impressive last chapter on micrometeorology and an appendix on meteorological observations, the rest of the book is concerned with weather forecasting. After a gentle introduction with the Bergeron theory of depressions, the mettle of the average reader will be sharply tested by the succeeding section on dynamics where, within a dozen pages, vorticity, development theory with definitions of barotropic and baroclinic changes, and Rossby waves are treated without mathematics. This is a prodigious task, some would say an impossible one and it has been performed here surely as well as it could conceivably be in a descriptive manner. Its purpose is to provide the reader with the background essential to the understanding of the principles of numerical forecasting. Before he reaches this, however, the reader is given breathing space in a judiciously interposed chapter, containing a fascinating essay on professional forecasting. The only mathematics in the book appear in the chapter on Forecasting by Numbers, in which, after a very readable account of L. F. Richardson's pioneer work, the forecasting equation is derived for the simplest case of a one-parameter barotropic model and its application in a lattice system using the computer described. This section ends with an assessment of the possibilities of, and of the hazards attending the use of statistical methods in, long-range forecasting and an account of methods at present under trial.

In short, this is an excellent book written in a clear and attractive style, enlivened by engaging touches of dry humour. That it will certainly be relished by the professional meteorologist as well as by the general reader to whom it is addressed is a sure test of its quality.

J. PATON

The world around us. Editor, Sir Graham Sutton. 8½ in. × 5½ in., pp. vi + 122, illus., English Universities Press, 102 Newgate St., London, E.C.1, 1960. Price 16s.

This well produced little book contains six essays based on the 1958 Christmas lectures at the Royal Institution on the subject of the International Geophysical Year. J. A. Ratcliffe writes on the Ionosphere, J. M. Stagg on the Earth's Magnetism, R. L. F. Boyd on the Exploration of the Upper Atmosphere, Sir Graham Sutton, who edits the book, on the Lower Atmosphere and its Weather, G. E. R. Deacon on the Sea and its Problems and G. de Q. Robin on the Antarctic. The editor points out that the essays are designed to present an account of some of the problems that were tackled rather than a broad outline of the work of the International Geophysical Year, and that they therefore differ from the lectures on which they are based; the scope of the accounts is obviously much wider than could be embraced within the hour of a discourse, amply illustrated by demonstrations as is the tradition of the Royal Institution lectures. Each author provides a survey of the development of his subject to serve as an introduction and background to the problems examined and the result is a book that will be read with interest and pleasure by the layman and specialist alike.

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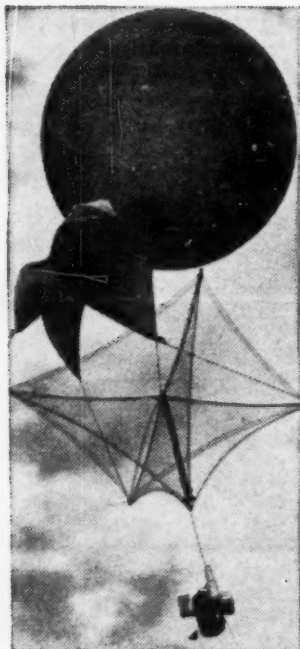
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